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MEMORANDUM REPORT BRL-MR-3906

BRL

HIGH VELOCITY FIRINGS OF SLUG PROJECTILES IN A DOUBLE-TRAVEL 120-MM GUN SYSTEM

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Test firings were planned and executed by the Interior Ballistics Division (IBD) of the Ballistic Research Laboratory (BRL) to support high velocity, scaled projectile firings for the Terminal Ballistics Division (TBD) of BRL. IBD conducted a computer evaluation of gun propellants available to TBD using the interior ballistic code IBHVG2, then verified the results with a series of slug projectile firings at BRL's Sandy Point (Range 18) large caliber firing facility.

Interior ballistic results from the computer evaluation were compared with corresponding data from the slug firings and the first series of scaled projectile firings conducted by TBD.

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1. INTRODUCTION

The objective of the Terminal Ballistic Division's (TBD) firing program was to routinely launch a specific Armor Piercing Fin Stabilized Discarding Sabot (APFSDS) projectile at muzzle velocities of 2500 m/s. The method chosen to achieve this level of performance involved launching a scaled projectile from a double travel 120-mm gun system. The terminal ballistic tests focused on the high velocity performance of current penetrator and armor technologies.

To avoid the possibility of overpressuring the gun system, the Interior Ballistics Division (IBD) was tasked with evaluating the available lots of propellant to come up with the highest performance charge possible given the initial constraints presented by TBD. This charge configuration was then tested using aluminium slug projectiles to avoid the unnecessary expenditure of APFSDS projectiles. The best propulsion charge was then mated with APFSDS projectiles for armor testing. It was also desired to photograph the round after muzzle exit to determine if the projectile fins were still intact.

2. INITIAL CONSTRAINTS

2.1 Gun. The selection of an existing 120-mm gun system defined the chamber volume as 0.438 m^3. The particular 120-mm test system chosen was the 2X ballistic tube, serial number 021. This tube has a projectile travel of 9.39 m. A sketch of the 120-mm 2X ballistic tube is presented in Figure 1.

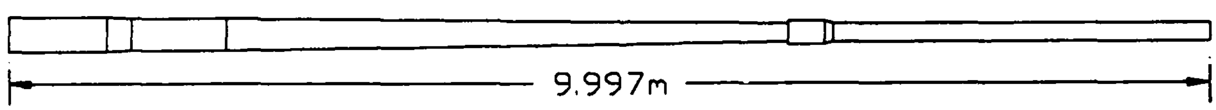

Figure 1. 120-mm Double Travel Gun Tube.

2.2 Projectile. TBD's test projectile was a depleted uranium alloy (U-.75Ti) rod with a standard, four piece, aluminum sabot assembly. The launch package had a nominal mass of 3 kg. The volume of the tail section behind the rear bourrelet was 0.0048 m^3. The rod had a length to diameter ratio (l/d) of 20. A sketch of the rod is shown in Figure 2.

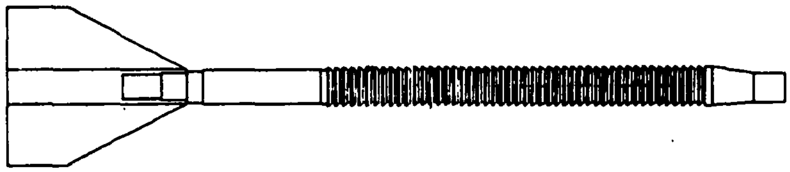

Figure 2. Scaled, Long Rod Penetrator.

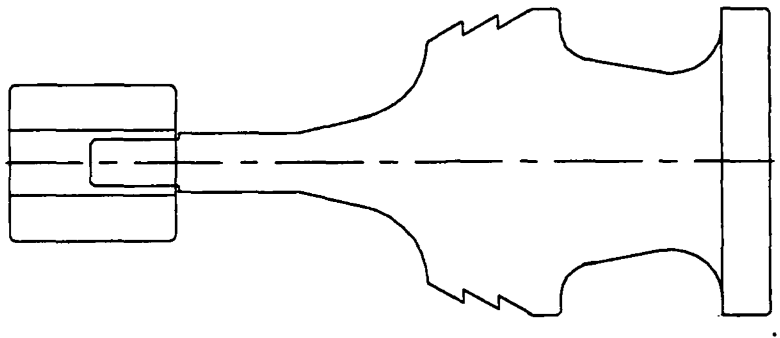

Figure 3. Aluminium Slug Projectile.

The aluminium slug rounds, fired at Range 18, had the same mass, tail volume, and obturator configuration as TBD's test round. A sketch of the slug projectile is presented in Figure 3. It was designed by TBD using finite element analysis software and an automated network Computer Aided Drafting (CAD) package.

2.3 Propelling Charge. To facilitate ammunition assembly and loading, the propelling charge was limited to the volume contained in a standard 120-mm combustible cartridge case. Granular propellant was used because of the extra time, manpower and materials required to fabricate a sufficient quantity of any of the more exotic, high performance propelling charges. Excessive time delays involved in ordering a custom production lot of propellant limited the selection of a propellant to lots currently in inventory.

Since the intrusion of the projectile tail boom into the propelling charge was minimal, an M125 bayonet primer was used. This primer extended well into the gun chamber, thus distributing the ignition pulse evenly throughout the relatively impermeable granular propellant bed. Distributed ignition reduced the chances of catastrophic pressure waves forming in the propellant bed.

3. PROPELLANT EVALUATION

IBHVG2 (Anderson 1987), a lumped parameter interior ballistic code, was utilized to determine if the most readily available lots of propellant (JA2, 19 perf, hex, lot no. RAD-PD-050-1 and M30, 19 perf, hex, lot no. RAD-PE-472-136) were suitable for this test. Because of the experimental nature of the extended travel gun tube and a lack of experience in modeling this specific 120-mm system, several system parameters were varied within the code input database. These parameters were chamber volume (dependant on projectile afterbody volume) and maximum propellant mass (dependant predominantly on grain size). The range of velocity values produced by the code run should have bracketed the experimental values. Appendix A contains the IBHVG2 input data base for the JA2 and the M30 propellant. Appendix B contains the tabular output from the IBHVG2 runs for the JA2 and M30 propellant.

The IBHVG2 results indicated that neither propelling charge was capable of achieving the desired muzzle exit velocity of 2500 m/s, even if the propellants were heated to 63°C. It was determined, however, that the predicted "hot" (63°C) velocities were high enough to warrant continuation of the program with the two selected propellants.

Because of uncertainty in the burning rate of the M30 propellant the interior ballistic code results could not be interpreted to yield a clear indication of which propellant was best suited for this program. The M30 grains were much smaller and would allow for a higher propellant loading density, but the JA2 contained more energy per unit mass. Loading tests indicated that a maximum charge mass of 9.18 kg was possible for the M30 propellant, as compared to a maximum of 8.73 kg for JA2. No burning rate data were found for M30 propellant at the conditioning temperature of 63°C, so burning rate data from a 50°C test were utilized. The first group of slug firings would be used to select which type of propellant would be used for the remainder of the program.

4. GUN FIRINGS

4.1 Instrumentation. Each round was instrumented with two M11 pressure gauges to record peak chamber pressure. The gauges were attached to the stub case retaining clip during loading to facilitate retrieving them from the gun after firing. A 15 GHz, in-bore, microwave interferometer was used to measure the muzzle velocity of each slug round. The velocity of the APFSDS rounds was measured down range near the target (striking velocity) through the use of a flash X-ray system. Two 35-mm smear cameras were used to check the fin integrity of each slug round. The cameras were located approximately 12 m from the gun muzzle.

4.2 Slug Firings. All slug firings were performed at IBD's Range 18 large caliber firing facility. Data from the slug firings are contained in Table 1.

The first two slug rounds fired were an equal charge mass comparison of the JA2 and M30 propelling charges. Both rounds were conditioned at 63°C for 24 hours prior to firing. The performance of the JA2 round was much better than predicted by IBHVG2, while the M30 round's performance was much less than predicted by IBHVG2. Based on these results, the decision was made to use the JA2 propellant for the remainder of the slug tests.

The remaining three slug rounds were used to bracket the performance of the JA2 propelling charge. It should be noted that because of firing delays the 8.8 kg round was conditioned at 63°C for 48 hours, while the 8.73 kg round was conditioned for 24 hours. This is one factor which could have influenced the lower muzzle velocity on the round with the larger charge mass. The lack of piezoelectric pressure transducers, excluded because of requirements to not alter the gun tube, made further analysis for ignition anomalies impossible.

Both 7.27 kg slug rounds showed little or no fin damage on the smear camera photographs. The smear photographs of the other three rounds were unreadable due to the presence of muzzle gases and/or burning of the slug projectile assembly.

Table 1. Slug Firing Data.

PROPELLANT TYPE	CHARGE MASS	PEAK CHAMBER PRESSURE	MUZZLE VELOCITY
M30	7.27 kg (16.0 lb)	316 MPa (45.9 kpsi)	2035 m/s (6677 ft/s)
JA2	7.27 kg (16.0 lb)	300 MPa (43.5 kpsi)	2085 m/s (6841 ft/s)
JA2	7.95 kg (17.5 lb)	403 MPa (58.4 kpsi)	2279 m/s (7477 ft/s)
JA2	8.73 kg (19.2 lb)	514 MPa (74.6 kpsi)	2475 m/s (8120 ft/s)
JA2	8.8 kg (19.35 lb)	527 MPa (76.4 kpsi)	2466 m/s (8091 ft/s)

4.3 APFSDS Firings. APFSDS firings were performed at TBD's Range 9 and Range 14 firing facilities. Like the slug tests, peak chamber pressures were measured with M11 gauges. Flash X-rays, for measurement of striking velocity, were positioned in close proximity to the target. Since the targets were generally 70 m to 76 m (230' to 250') down range of the gun, an additional flash X-ray station was positioned at the muzzle to record the launch event. Muzzle velocity was estimated to be 10 to 15 m/s higher than the down range (striking) velocity. JA2 propellant, conditioned to 63°C, was used in all of the APFSDS firings

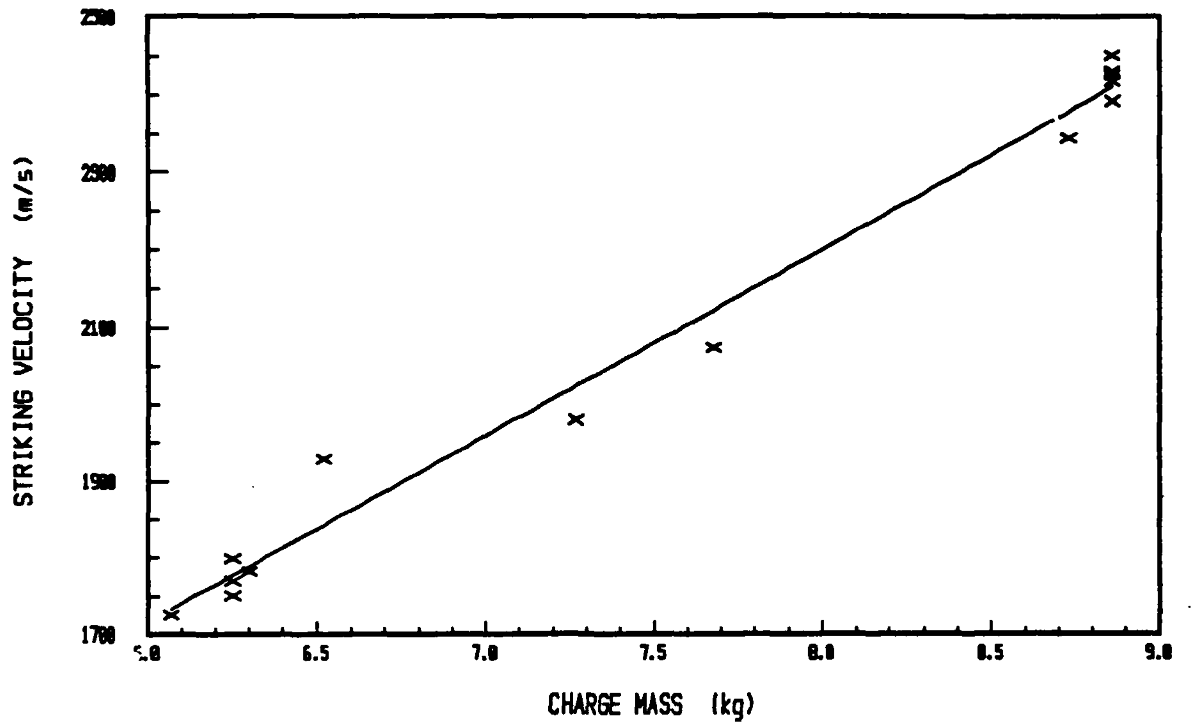

Figure 4. Chamber Pressure vs. Charge Mass (APFSDS Rounds).

Data from the APFSDS rounds are shown in Table 2. Figure 4 shows a plot of striking velocity versus charge mass. The straight line represents a linear fit to the data points. The data exhibit the reasonably linear relationship between charge mass and striking velocity desired in this type of experiment.

Table 2. APFSDS Firing Data.

ID #	CHARGE MASS	PEAK CHAMBER PRESSURE	STRIKING VELOCITY
1240	7.27 kg (16.0 lb)	274 MPa (39.8 kpsi)	1979 m/s (6493 ft/s)
1241	8.73 kg (19.2 lb)	455 MPa (66.0 kpsi)	2344 m/s (7690 ft/s)
1242	7.68 kg (16.9 lb)	318 MPa (46.1 kpsi)	2074 m/s (6804 ft/s)
1243	8.86 kg (19.5 lb)	487 MPa (70.6 kpsi)	2391 m/s (7844 ft/s)
2044	6.52 kg (14.35 lb)	249 MPa (36.1 kpsi)	1927 m/s (6322 ft/s)
2045	6.07 kg (13.35 lb)	190 MPa (27.5 kpsi)	1725 m/s (5659 ft/s)
2046	8.86 kg (19.5 lb)	541 MPa (78.5 kpsi)	2451 m/s (8041 ft/s)
2047	8.86 kg (19.5 lb)	524 MPa (76.0 kpsi)	2425 m/s (7956 ft/s)
2048	8.86 kg (19.5 lb)	531 MPa (77.0 kpsi)	2430 m/s (7972 ft/s)
2049	8.86 kg (19.5 lb)	501 MPa (72.6 kpsi)	2417 m/s (7930 ft/s)
2050	6.25 kg (13.75 lb)	210 MPa (30.4 kpsi)	1798 m/s (5899 ft/s)
2051	6.25 kg (13.75 lb)	198 MPa (28.7 kpsi)	1750 m/s (5741 ft/s)
2052	6.25 kg (13.75 lb)	204 MPa (29.7 kpsi)	1769 m/s (5804 ft/s)
2053	6.30 kg (13.85 lb)	205 MPa (29.8 kpsi)	1782 m/s (5846 ft/s)

Generally, the velocities of the APFSDS rounds were lower than those of the slug rounds with equal charge masses, although the peak chamber pressures were comparable. This could be due to the differences in projectile/tube interactions and/or differences in launch dynamics between the monobloc slug and the multiple part APFSDS projectiles. The small number of slug firings precluded more rigorous comparisons between firings of the two projectile types.

The most striking features of APFSDS round data were the large variations in pressure and velocity for the maximum charge (8.86 kg) rounds. While the velocities did seem to correspond to the maximum chamber pressure, there is not enough data to make conclusions concerning the pressure variances.

During the APFSDS tests (after round 1242) a gauge hole, tapped for a pressure transducer was discovered in the chamber of the double travel gun. It is unlikely that this hole reduced the maximum pressure of any of the test rounds, but it is unfortunate that this port was not used while the gun was at R18. Gas erosion from nine prior rounds had rendered the port unusable, so it was welded shut.

5. CONCLUSIONS

Although projectile velocities fell somewhat short of the initial goal, the APFSDS tests proved very successful, and will be documented elsewhere (Keele, Rapacki, and Bruchey 1990). It is hoped that future studies of this type can be flexible enough to take advantage of novel propulsion techniques utilized in extended gun tube/light weight projectile hypervelocity programs currently in progress in IBD (Ruth 1988; Ruth 1989).

Studies of this type not only provide terminal ballistics researchers with a reliable research tool, they also provide valuable interior ballistic data on the dynamics of hypervelocity propulsion.

6. REFERENCES

Anderson, R.D. and K.D. Fickie, "IBHVG2 -- A User's Guide." BRL-TR-2829, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, July 1987.

Keele, M., E. Rapacki, and W. Bruchey Jr., "High Velocity Terminal Ballistic Performance of a Uranium Alloy Long Rod Penetrator." Proceedings of the 12th International Symposium on Ballistics, Volume I, pp. 42 - 51, San Antonio, TX, October 1990.

Ruth, C.R. and A.W. Horst, "Detailed Characterization of Hypervelocity Firings in a Long 120-mm Gun." Proceedings of the 25th JANNAF Combustion Meeting, CPIA Publication 498, Volume IV, pp. 511 - 527, Huntsville, AL, October 1988.

Ruth, C.R., F.W. Robbins and A.W. Horst, "Experimental Hypervelocity Firings Using Stick and Granular Propellant Configurations." Proceedings of the 26th JANNAF Combustion Meeting, CPIA Publication 529, Volume III, pp. 263 - 278, Pasadena, CA, October 1989.

APPENDIX A:

IBHVG2 INPUT DECKS

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IBHVG2 INPUT DECK, HOT JA2, 2X 120-mm GUN

```
$HEAT
    TSHL = 0.00450     CSHL = 1848     RSHL = 0.284
    TWAL = 293         H0  = 0.0648    HL  = 1
$GUN
    NAME = 'DOUBLE TRAVEL 120MM GUN JA2'   CHAM = 617.3     GRVE = 4.724
    LAND = 4.724      G/L  = 1.     TRAV = 369.66
    TWST = 99
$PROJ
    NAME = 'APFSDS'   PRWT = 6.60
$PDIS
 SHOW='CHAM' DECK='GUN'
$PDIS
 SHOW='CHWT' DECK='PROP' NTH=2
$PDIS
 SHOW='PMAX' DECK='OUT'
$PDIS
 SHOW='VMUZ' DECK='OUT'
$PDIS
 SHOW='ZMUZ(2)' DECK='OUT'
$PDIS
 SHOW='X@BO(2)' DECK='OUT'
$RESI
    NPTS = 4         AIR  = 1
    TRAV =    0,   .8,    3.0,   369
    PRES =   100,  2500,  100,  100
$INFO
   RUN  = 'TBD 120 DOUBLE TRAVEL JA2 HOT '   DELT = 5E-5    DELP = 5E-5
    GRAD = 2          POPT = 1,1,1,0,2   SOPT = 0
    EPS  = 0.002      CONP = 0
$RECO
    NAME = 'NONE'     RECO = 0        RCWT = 0
$PRIM
   NAME = 'BENITE'    CHWT = 0.00347
             GAMA = 1.25      FORC = 212500
    COV  = 30         TEMP = 2000
$PROP
   NAME = 'BENITE'    CHWT = 0.06653   GRAN = 'CORD'
    RHO  = 0.06      GAMA = 1.25      FORC = 212500
    COV  = 30        TEMP = 2000      EROS = 0.00000
    ALPH = 0         BETA = 27       IGNC = 0
   LEN  = 9.998      DIAM = 0.078
$PARA
 VARY='CHWT' DECK='PROP' NTH=2 FROM=16 TO=22 BY=.25
$PARA
  VARY='CHAM' DECK='GUN' FROM=597.3 TO=647.3 BY=10
$PROP
   NAME = 'JA2 19HX '   CHWT = 18.6     GRAN = '19H'
   RHO  = 0.05732    GAMA = 1.2257    FORC = 382152
    COV  = 27.48      TEMP = 3400     EROS = 0.0000000
  NTBL=4 PR4L= 2000,4000,10000,40000 BR4L= 1.192,1.648,3.225,11.01
   LEN=.637  DIAM=.559 PD=.022 WEB = .078
$PROP
    NAME = 'FNC CASE'   CHWT = 1.41     GRAN = '1PF'
     RHO  = 0.04      GAMA = 1.258
 FRCP= ,150000,150000  FRCE= ,150000,150000 FRCL(4)=200000
     COV  = 27.927      TEMP = 1610      EROS = 0.00
 IGNS(3)=2  THRS(3)=200   DEPP= , .015 , .0155  DEPE= , .015 , .0155
 NTBL=2
 PR2P=1000,10000  BR2P=.5,2.4   PR3P=1000,10000  BR3P=.5,2.4
 PR2E=1000,10000  BR2E=.5,2.4   PR3E=1000,10000  BR3E=.5,2.4
 PR4L=1000,10000  BR4L=.5,10
    LEN  =  18      DIAM = 6.17    PD   = 6.01
    WI  =  .08
$PROP
    NAME = 'KRAFT CASE'   CHWT = .21     GRAN = '1PF'
    RHO  = 0.04      GAMA = 1.2734     FORC = 95726
    COV  = 9.883      TEMP = 1054      EROS = 0.00
```

IBHVG2 INPUT DECK, HOT JA2, 2X 120-mm GUN (con't)

```
   ALPH =  1       BETA = 0.00001  IGNC = 0
   LEN  = 3.4      DIAM = 6.17     PD   = 6.01
   WI =  .08
$END
```

IBHVG2 INPUT DECK, HOT M30, 2X 120-mm GUN

```
$HEAT
     TSHL = 0.00450      CSHL = 1848      RSHL = 0.284
    TWAL = 293        H0  = 0.0648    HL  = 1
$GUN
    NAME = 'DOUBLE TRAVEL 120MM GUN M30'   CHAM = 617.3      GRVE = 4.724
    LAND = 4.724        G/L  = 1.      TRAV = 369.66
    TWST = 99
$PROJ
    NAME = 'APFSDS'   PRWT = 6.60
$PDIS
 SHOW='CHAM' DECK='GUN'
$PDIS
 SHOW='CHWT' DECK='PROP' NTH=2
$PDIS
 SHOW='PMAX' DECK='OUT'
$PDIS
 SHOW='VMUZ' DECK='OUT'
$PDIS
 SHOW='ZMUZ(2)' DECK='OUT'
$PDIS
 SHOW='X@BO(2)' DECK='OUT'
$RESI
    NPTS = 4          AIR  = 1
    TRAV =    0,  .8,    3.0,   369.66
    PRES =   100,  2500,  100,  100
$INFO
    RUN  = 'TBD 120 DOUBLE TRAVEL M30 50C '   DELT = 5E-5     DELP = 5E-5
    GRAD = 2          POPT = 1,1,1,0,2   SOPT = 0
    EPS  = 0.002       CONP = 0
$RECO
    NAME = 'NONE'      RECO = 0        RCWT = 0
$PRIM
    NAME = 'BENITE'     CHWT = 0.00347
              GAMA = 1.25      FORC = 212500
    COV  = 30          TEMP = 2000
$PROP
    NAME = 'BENITE'     CHWT = 0.06653   GRAN = 'CORD'
    RHO  = 0.06       GAMA = 1.25       FORC = 212500
    COV  = 30         TEMP = 2000      EROS = 0.00000
    ALPH = 0          BETA = 27        IGNC = 0
    LEN  = 9.998       DIAM = 0.078
$PARA
 VARY='CHWT' DECK='PROP' NTH=2 FROM=16 TO=22 BY=.25
$PARA
 VARY='CHAM' DECK='GUN' FROM=597.3 TO=647.3 BY=10
$PROP
   NAME = 'M30 19HX RAD 472-136 '    CHWT = 15.0     GRAN = '19H'
   RHO  = 0.06004     GAMA = 1.2385      FORC = 360455
    COV  = 28.42       TEMP = 3028       EROS = 0.0000000
  NTBL=9 PR4L= 1000,3000,5000,10000,15000,20000,25000,35000,40000
   BR4L= 0.3713,1.4366,1.821,2.5774,3.552,4.5463,5.4262,6.9885,7.4322
   LEN=.508  DIAM=.395 PD=.020 WEB = .050
$PROP
    NAME = 'FNC CASE'    CHWT = 1.41      GRAN = '1PF'
    RHO  = 0.04       GAMA = 1.258
 FRCP= ,150000,150000  FRCE= ,150000,150000 FRCL(4)=200000
    COV  = 27.927       TEMP = 1610       EROS = 0.00
 IGNS(3)=2  THRS(3)=200   DEPP= , .015 , .0155  DEPE= , .015 , .0155
 NTBL=2
 PR2P=1000,10000  BR2P=.5,2.4   PR3P=1000,10000  BR3P=.5,2.4
 PR2E=1000,10000  BR2E=.5,2.4   PR3E=1000,10000  BR3E=.5,2.4
 PR4L=1000,10000  BR4L=.5,10
    LEN  = 18      DIAM = 6.17     PD  = 6.01
    WI =  .08
$PROP
    NAME = 'KRAFT CASE'     CHWT = .21      GRAN = '1PF'
    RHO  = 0.04       GAMA = 1.2734      FORC = 95726
```

IBHVG2 INPUT DECK, HOT M30, 2X 120-mm GUN (con't)

```
    COV  = 9.883      TEMP = 1054     EROS = 0.00
    ALPH =  1         BETA = 0.00001  IGNC = 0
    LEN  = 3.4        DIAM = 6.17     PD   = 6.01
    WI =  .08
$END
```

APPENDIX B:

IBHVG2 DATA OUTPUT

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IBHVG2 OUTPUT DECK, HOT JA2, 2X 120-mm GUN (output table only)

CHAM VOL $in.^3$	CHARGE MASS lb.	PMAX psi.	MUZZLE VEL. ft/s	PROP. BURNED. @ MUZZ	TRAVEL @ BURNOUT in.
597.30	16.000	38229.	6434.8	0.97378	369.66
597.30	16.250	39889.	6535.1	0.97894	369.66
597.30	16.500	41634.	6635.7	0.98352	369.66
597.30	16.750	43454.	6736.7	0.98765	369.66
597.30	17.000	45373.	6837.0	0.99058	369.66
597.30	17.250	47392.	6937.1	0.99290	369.66
597.30	17.500	49505.	7035.8	0.99462	369.66
597.30	17.750	51732.	7135.1	0.99608	369.66
597.30	18.000	54081.	7234.4	0.99748	369.66
597.30	18.250	56549.	7331.0	0.99806	369.66
597.30	18.500	59154.	7426.4	0.99882	369.66
597.30	18.750	61915.	7521.0	0.99928	369.66
597.30	19.000	64818.	7621.6	1.0000	366.93
597.30	19.250	67902.	7715.6	1.0000	369.37
597.30	19.500	71172.	7809.4	1.0000	353.01
597.30	19.750	74631.	7907.8	1.0000	336.53
597.30	20.000	78313.	8003.4	1.0000	314.69
597.30	20.250	82233.	8099.2	1.0000	297.14
597.30	20.500	86410.	8193.3	1.0000	283.87
597.30	20.750	90870.	8288.7	1.0000	265.50
597.30	21.000	95657.	8386.9	1.0000	251.63
597.30	21.250	0.10077E+06	8482.2	1.0000	237.35
597.30	21.500	0.10627E+06	8581.8	1.0000	227.65
597.30	21.750	0.11223E+06	8678.4	1.0000	212.77
597.30	22.000	0.11863E+06	8779.1	1.0000	202.50
607.30	16.000	37288.	6406.2	0.97307	369.66
607.30	16.250	38882.	6506.5	0.97856	369.66
607.30	16.500	40551.	6606.5	0.98321	369.66
607.30	16.750	42300.	6706.2	0.98714	369.66
607.30	17.000	44135.	6805.5	0.99042	369.66
607.30	17.250	46058.	6903.2	0.99252	369.66
607.30	17.500	48077.	7001.3	0.99432	369.66
607.30	17.750	50200.	7098.1	0.99599	369.66
607.30	18.000	52429.	7195.0	0.99705	369.66
607.30	18.250	54780.	7291.2	0.99802	369.66
607.30	18.500	57251.	7387.6	0.99892	369.66
607.30	18.750	59856.	7481.1	0.99934	369.66
607.30	19.000	62609.	7574.8	0.99974	369.66
607.30	19.250	65512.	7671.4	0.99971	369.66
607.30	19.500	68583.	7764.1	1.0000	356.40
607.30	19.750	71836.	7859.3	1.0000	339.82
607.30	20.000	75282.	7953.0	1.0000	322.80
607.30	20.250	78941.	8044.1	1.0000	305.15
607.30	20.500	82834.	8142.3	1.0000	287.47
607.30	20.750	86978.	8233.9	1.0000	273.85
607.30	21.000	91400.	8330.9	1.0000	255.33
607.30	21.250	96126.	8420.7	1.0000	245.71
607.30	21.500	0.10119E+06	8519.4	1.0000	231.36
607.30	21.750	0.10662E+06	8615.8	1.0000	216.57
607.30	22.000	0.11246E+06	8710.4	1.0000	206.21
617.30	16.000	36409.	6378.3	0.97260	369.66
617.30	16.250	37941.	6477.2	0.97790	369.66
617.30	16.500	39546.	6575.8	0.98259	369.66
617.30	16.750	41222.	6673.6	0.98678	369.66
617.30	17.000	42978.	6771.2	0.98981	369.66
617.30	17.250	44827.	6869.3	0.99231	369.66
617.30	17.500	46753.	6966.6	0.99426	369.66
617.30	17.750	48780.	7062.5	0.99566	369.66
617.30	18.000	50914.	7159.2	0.99710	369.66
617.30	18.250	53142.	7251.9	0.99775	369.66
617.30	18.500	55494.	7345.5	0.99857	369.66
617.30	18.750	57973.	7441.9	0.99916	369.66

IBHVG2 OUTPUT DECK, HOT JA2, 2X 120-mm GUN (output table only) (con't)

CHAM VOL $in.^3$	CHARGE MASS lb.	PMAX psi.	MUZZLE VEL. ft/s	PROP. BURNED. @ MUZZ	TRAVEL @ BURNOUT in.
617.30	19.000	60573.	7536.1	1.0000	369.14
617.30	19.250	63319.	7626.4	1.0000	366.84
617.30	19.500	66230.	7721.1	1.0000	360.01
617.30	19.750	69283.	7812.3	1.0000	343.33
617.30	20.000	72528.	7905.0	1.0000	326.38
617.30	20.250	75969.	7997.6	1.0000	308.98
617.30	20.500	79603.	8085.9	1.0000	290.98
617.30	20.750	83470.	8182.3	1.0000	277.70
617.30	21.000	87596.	8272.0	1.0000	263.79
617.30	21.250	91970.	8367.2	1.0000	249.75
617.30	21.500	96655.	8458.7	1.0000	235.22
617.30	21.750	0.10166E+06	8553.1	1.0000	220.56
617.30	22.000	0.10703E+06	8648.0	1.0000	210.28
627.30	16.000	35585.	6351.4	0.97197	369.66
627.30	16.250	37063.	6449.6	0.97754	369.66
627.30	16.500	38602.	6547.3	0.98229	369.66
627.30	16.750	40217.	6644.7	0.98613	369.66
627.30	17.000	41907.	6742.0	0.98976	369.66
627.30	17.250	43673.	6837.7	0.99197	369.66
627.30	17.500	45524.	6932.0	0.99384	369.66
627.30	17.750	47463.	7028.0	0.99565	369.66
627.30	18.000	49497.	7121.9	0.99676	369.66
627.30	18.250	51630.	7216.7	0.99781	369.66
627.30	18.500	53874.	7310.6	0.99881	369.66
627.30	18.750	56227.	7404.4	0.99941	369.66
627.30	19.000	58705.	7495.1	0.99957	369.66
627.30	19.250	61313.	7586.7	0.99972	369.66
627.30	19.500	64060.	7677.3	1.0000	363.64
627.30	19.750	66958.	7768.5	1.0000	347.15
627.30	20.000	70019.	7860.2	1.0000	330.19
627.30	20.250	73249.	7950.5	1.0000	312.85
627.30	20.500	76672.	8040.6	1.0000	295.09
627.30	20.750	80302.	8131.6	1.0000	281.65
627.30	21.000	84144.	8221.4	1.0000	267.86
627.30	21.250	88233.	8312.6	1.0000	253.79
627.30	21.500	92599.	8403.4	1.0000	239.44
627.30	21.750	97230.	8495.2	1.0000	224.75
627.30	22.000	0.10219E+06	8584.1	1.0000	214.37
637.30	16.000	34811.	6325.0	0.97126	369.66
637.30	16.250	36236.	6422.4	0.97697	369.66
637.30	16.500	37725.	6519.1	0.98172	369.66
637.30	16.750	39276.	6615.1	0.98566	369.66
637.30	17.000	40901.	6711.0	0.98906	369.66
637.30	17.250	42601.	6806.9	0.99187	369.66
637.30	17.500	44375.	6901.1	0.99385	369.66
637.30	17.750	46235.	6995.5	0.99543	369.66
637.30	18.000	48190.	7089.7	0.99697	369.66
637.30	18.250	50226.	7181.3	0.99761	369.66
637.30	18.500	52368.	7273.5	0.99859	369.66
637.30	18.750	54622.	7365.7	0.99924	369.66
637.30	19.000	56974.	7454.3	0.99941	369.66
637.30	19.250	59457.	7547.5	1.0000	365.44
637.30	19.500	62073.	7637.1	1.0000	367.56
637.30	19.750	64814.	7727.5	1.0000	351.13
637.30	20.000	67709.	7816.4	1.0000	334.21
637.30	20.250	70774.	7905.0	1.0000	316.90
637.30	20.500	73991.	7994.1	1.0000	299.23
637.30	20.750	77409.	8083.1	1.0000	285.85
637.30	21.000	81024.	8174.2	1.0000	267.50
637.30	21.250	84855.	8264.1	1.0000	258.15
637.30	21.500	88924.	8352.3	1.0000	243.81
637.30	21.750	93253.	8436.6	1.0000	228.98

IBHVG2 OUTPUT DECK, HOT JA2, 2X 120-mm GUN (output table only) (con't)

CHAM VOL in.^{3}	CHARGE MASS lb.	PMAX psi.	MUZZLE VEL. ft/s	PROP. BURNED. @ MUZZ	TRAVEL @ BURNOUT in.
637.30	22.000	97857.	8529.8	1.0000	218.95
647.30	16.000	34084.	6300.1	0.97086	369.66
647.30	16.250	35462.	6396.1	0.97635	369.66
647.30	16.500	36895.	6491.9	0.98118	369.66
647.30	16.750	38393.	6587.4	0.98530	369.66
647.30	17.000	39961.	6682.3	0.98871	369.66
647.30	17.250	41595.	6776.7	0.99157	369.66
647.30	17.500	43304.	6868.7	0.99355	369.66
647.30	17.750	45092.	6961.6	0.99497	369.66
647.30	18.000	46961.	7055.4	0.99640	369.66
647.30	18.250	48920.	7148.2	0.99786	369.66
647.30	18.500	50969.	7238.3	0.99821	369.66
647.30	18.750	53121.	7327.8	0.99886	369.66
647.30	19.000	55375.	7419.4	0.99979	369.66
647.30	19.250	57743.	7509.1	1.0000	369.47
647.30	19.500	60228.	7595.6	1.0000	366.87
647.30	19.750	62843.	7686.1	1.0000	355.19
647.30	20.000	65596.	7776.4	1.0000	333.88
647.30	20.250	68491.	7863.9	1.0000	321.18
647.30	20.500	71544.	7949.3	1.0000	303.52
647.30	20.750	74774.	8039.1	1.0000	285.61
647.30	21.000	78172.	8125.1	1.0000	271.89
647.30	21.250	81778.	8214.2	1.0000	257.94
647.30	21.500	85607.	8297.5	1.0000	248.15
647.30	21.750	89645.	8386.3	1.0000	233.67
647.30	22.000	93945.	8474.2	1.0000	223.53

IBHVG2 OUTPUT DECK, HOT M30, 2X 120-mm GUN (output table only)

CHAM VOL in.^{3}	CHARGE MASS lb.	PMAX psi.	MUZZLE VEL. ft/s	PROP. BURNED. @ MUZZ	TRAVEL @ BURNOUT in.
597.30	16.000	45797.	6833.4	1.0000	367.12
597.30	16.250	47383.	6895.2	1.0000	364.21
597.30	16.500	48985.	6954.0	1.0000	356.73
597.30	16.750	50605.	7013.3	1.0000	348.94
597.30	17.000	52253.	7069.1	1.0000	344.85
597.30	17.250	53930.	7124.2	1.0000	340.55
597.30	17.500	55642.	7177.5	1.0000	335.90
597.30	17.750	57389.	7231.9	1.0000	331.08
597.30	18.000	59180.	7283.5	1.0000	325.97
597.30	18.250	61006.	7333.0	1.0000	324.89
597.30	18.500	62879.	7382.0	1.0000	319.27
597.30	18.750	64802.	7430.7	1.0000	317.86
597.30	19.000	66771.	7481.0	1.0000	316.38
597.30	19.250	68793.	7524.6	1.0000	310.07
597.30	19.500	70869.	7573.9	1.0000	308.28
597.30	19.750	73005.	7622.9	1.0000	306.31
597.30	20.000	75200.	7667.0	1.0000	304.08
597.30	20.250	77466.	7710.0	1.0000	301.67
597.30	20.500	79787.	7757.0	1.0000	303.82
597.30	20.750	82185.	7800.5	1.0000	301.21
597.30	21.000	84659.	7844.4	1.0000	298.59
597.30	21.250	87216.	7889.2	1.0000	295.78
597.30	21.500	89861.	7930.4	1.0000	297.44
597.30	21.750	92591.	7971.3	1.0000	294.36
597.30	22.000	95428.	8012.1	1.0000	295.81
607.30	16.000	44911.	6818.1	1.0000	367.29
607.30	16.250	46478.	6881.6	1.0000	360.51
607.30	16.500	48050.	6942.5	1.0000	353.19
607.30	16.750	49635.	7000.7	1.0000	345.39
607.30	17.000	51244.	7056.5	1.0000	341.42
607.30	17.250	52882.	7113.2	1.0000	337.18
607.30	17.500	54551.	7166.9	1.0000	332.63
607.30	17.750	56250.	7218.9	1.0000	327.80
607.30	18.000	57990.	7271.0	1.0000	322.74
607.30	18.250	59765.	7324.4	1.0000	317.53
607.30	18.500	61584.	7371.5	1.0000	316.24
607.30	18.750	63444.	7420.7	1.0000	314.90
607.30	19.000	65352.	7468.3	1.0000	308.90
607.30	19.250	67301.	7516.9	1.0000	307.23
607.30	19.500	69308.	7564.4	1.0000	305.36
607.30	19.750	71366.	7611.4	1.0000	303.39
607.30	20.000	73482.	7654.4	1.0000	301.14
607.30	20.250	75651.	7701.5	1.0000	298.87
607.30	20.500	77885.	7747.2	1.0000	296.45
607.30	20.750	80194.	7788.5	1.0000	293.76
607.30	21.000	82559.	7835.5	1.0000	295.75
607.30	21.250	85000.	7876.2	1.0000	292.88
607.30	21.500	87518.	7922.1	1.0000	290.07
607.30	21.750	90122.	7963.9	1.0000	291.66
607.30	22.000	92818.	8005.4	1.0000	288.56
617.30	16.000	44043.	6800.6	1.0000	367.36
617.30	16.250	45611.	6866.1	1.0000	356.72
617.30	16.500	47158.	6927.9	1.0000	349.58
617.30	16.750	48715.	6987.3	1.0000	341.93
617.30	17.000	50292.	7043.9	1.0000	338.05
617.30	17.250	51894.	7099.7	1.0000	333.85
617.30	17.500	53520.	7153.4	1.0000	329.33
617.30	17.750	55179.	7207.0	1.0000	324.60
617.30	18.000	56868.	7258.1	1.0000	319.58
617.30	18.250	58598.	7310.4	1.0000	314.36
617.30	18.500	60359.	7359.2	1.0000	313.15
617.30	18.750	62164.	7410.6	1.0000	307.53

IBHVG2 OUTPUT DECK, HOT M30, 2X 120-mm GUN (output table only) (con't)

CHAM VOL in.^{3}	CHARGE MASS lb.	PMAX psi.	MUZZLE VEL. ft/s	PROP. BURNED. @ MUZZ	TRAVEL @ BURNOUT in.
617.30	19.000	64016.	7457.9	1.0000	305.97
617.30	19.250	65902.	7507.2	1.0000	304.35
617.30	19.500	67842.	7552.7	1.0000	302.43
617.30	19.750	69830.	7599.9	1.0000	296.07
617.30	20.000	71874.	7645.0	1.0000	293.81
617.30	20.250	73962.	7691.2	1.0000	296.00
617.30	20.500	76115.	7735.6	1.0000	293.64
617.30	20.750	78325.	7780.1	1.0000	291.09
617.30	21.000	80601.	7824.7	1.0000	288.45
617.30	21.250	82948.	7867.4	1.0000	285.58
617.30	21.500	85356.	7907.6	1.0000	287.18
617.30	21.750	87854.	7953.6	1.0000	284.34
617.30	22.000	90417.	7995.3	1.0000	285.79
627.30	16.000	43196.	6782.2	1.0000	363.26
627.30	16.250	44775.	6851.0	1.0000	353.01
627.30	16.500	46307.	6913.2	1.0000	345.97
627.30	16.750	47841.	6972.0	1.0000	342.53
627.30	17.000	49385.	7031.4	1.0000	334.68
627.30	17.250	50954.	7086.4	1.0000	330.54
627.30	17.500	52542.	7140.9	1.0000	326.11
627.30	17.750	54163.	7195.1	1.0000	321.41
627.30	18.000	55809.	7246.9	1.0000	316.48
627.30	18.250	57495.	7298.7	1.0000	311.31
627.30	18.500	59208.	7348.0	1.0000	310.16
627.30	18.750	60964.	7395.3	1.0000	304.43
627.30	19.000	62756.	7445.6	1.0000	303.05
627.30	19.250	64589.	7493.7	1.0000	297.01
627.30	19.500	66468.	7540.8	1.0000	295.11
627.30	19.750	68394.	7586.4	1.0000	293.12
627.30	20.000	70367.	7634.0	1.0000	291.06
627.30	20.250	72389.	7678.9	1.0000	288.79
627.30	20.500	74464.	7721.8	1.0000	286.27
627.30	20.750	76595.	7768.2	1.0000	288.32
627.30	21.000	78792.	7812.0	1.0000	285.66
627.30	21.250	81042.	7856.9	1.0000	282.97
627.30	21.500	83361.	7899.0	1.0000	280.10
627.30	21.750	85738.	7940.9	1.0000	281.60
627.30	22.000	88190.	7983.4	1.0000	278.45
637.30	16.000	42398.	6763.1	1.0000	363.20
637.30	16.250	43947.	6833.4	1.0000	353.15
637.30	16.500	45486.	6898.7	1.0000	346.50
637.30	16.750	46999.	6959.8	1.0000	339.17
637.30	17.000	48521.	7017.8	1.0000	331.33
637.30	17.250	50056.	7074.6	1.0000	327.30
637.30	17.500	51613.	7126.1	1.0000	322.78
637.30	17.750	53196.	7182.1	1.0000	318.31
637.30	18.000	54805.	7233.7	1.0000	313.36
637.30	18.250	56447.	7285.1	1.0000	308.28
637.30	18.500	58118.	7337.0	1.0000	302.95
637.30	18.750	59826.	7385.6	1.0000	301.61
637.30	19.000	61569.	7433.8	1.0000	300.09
637.30	19.250	63354.	7480.8	1.0000	294.10
637.30	19.500	65176.	7530.1	1.0000	292.37
637.30	19.750	67043.	7577.0	1.0000	290.40
637.30	20.000	68955.	7621.8	1.0000	288.27
637.30	20.250	70910.	7667.7	1.0000	286.05
637.30	20.500	72915.	7711.6	1.0000	283.67
637.30	20.750	74976.	7756.3	1.0000	281.14
637.30	21.000	77086.	7798.6	1.0000	282.90
637.30	21.250	79261.	7844.1	1.0000	280.26
637.30	21.500	81488.	7888.1	1.0000	277.40
637.30	21.750	83779.	7930.6	1.0000	279.01

'BHVG2 OUTPUT DECK, HOT M30, 2X 120-mm GUN (output table only) (con't)

CHAM VOL in.^{3}	CHARGE MASS lb.	PMAX psi.	MUZZLE VEL. ft/s	PROP. BURNED. @ MUZZ	TRAVEL @ BURNOUT in.
637.30	22.000	86144.	7973.7	1.0000	275.99
647.30	16.000	41643.	6746.7	1.0000	363.37
647.30	16.250	43147.	6816.0	1.0000	353.35
647.30	16.500	44693.	6882.4	1.0000	342.84
647.30	16.750	46194.	6944.3	1.0000	335.67
647.30	17.000	47695.	7003.8	1.0000	328.01
647.30	17.250	49203.	7060.7	1.0000	324.04
647.30	17.500	50732.	7115.8	1.0000	319.76
647.30	17.750	52278.	7169.5	1.0000	315.20
647.30	18.000	53857.	7221.0	1.0000	310.35
647.30	18.250	55456.	7272.6	1.0000	305.24
647.30	18.500	57091.	7323.9	1.0000	299.97
647.30	18.750	58751.	7374.0	1.0000	298.76
647.30	19.000	60454.	7421.9	1.0000	292.98
647.30	19.250	62186.	7469.4	1.0000	291.36
647.30	19.500	63959.	7516.5	1.0000	289.54
647.30	19.750	65771.	7565.1	1.0000	287.69
647.30	20.000	67627.	7609.2	1.0000	285.56
647.30	20.250	69524.	7653.3	1.0000	283.25
647.30	20.500	71465.	7700.2	1.0000	280.97
647.30	20.750	73460.	7746.0	1.0000	278.55
647.30	21.000	75501.	7788.5	1.0000	275.94
647.30	21.250	77600.	7832.7	1.0000	273.17
647.30	21.500	79744.	7873.1	1.0000	274.71
647.30	21.750	81958.	7919.0	1.0000	271.92
647.30	22.000	84230.	7962.0	1.0000	273.39

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